

Remarks

Claims 1-3 are currently pending in the application.

In the instant Amendment, claim 1 has been amended to recite continuously hot-dip galvanizing a high strength steel sheet in an all radiant tube type annealing furnace, and introducing a gas containing CO₂ in an amount of 1 to 100 wt% and a balance of N₂, H₂O, O₂, CO, and unavoidable impurities into the annealing furnace. Support for this amendment is found, for example, on p. 3, ll. 1-6, and p. 5, ll. 5-13 of the specification.

Accordingly, no new matter has been introduced by the present amendment.

Claim rejection under 35 U.S.C. §103

Claims 1-3 are rejected under 35 U.S.C. §103(a) as being unpatentable over JP 2001-279412 ("JP '412") in view of U.S. Patent No. 4,437,905 to Nitto, et al. ("US '905"). The Examiner contends that JP '412 discloses controlling in the atmosphere in the reducing zone the log (PH₂O/PH₂) of the water partial pressure and hydrogen partial pressure to log (PH₂O/PH₂) ≤ -0.8, which overlaps the claimed range of log (PH₂O/PH₂) ≤ -0.5. The Examiner also contends that the reducing zone of the continuous system hot-dipping line as disclosed by JP '412 reads on the claimed apparatus limitation of an all radiant tube type annealing furnace without an oxidizing zone and that when combined with US '905's teaching of O₂, CO₂ and CO in the atmosphere, renders the presently claimed invention obvious.

The present invention solves the problem of hot-dip galvanizing a high strength steel sheet containing elements such as Si and P using an all radiant tube type annealing furnace without an oxidizing zone. The all radiant furnace of the present invention contains a preheating furnace, but the heating is carried out by the radiant tube. As shown in Figure 1 of the present application, the heating zone, the soaking zone (reducing zone), and the cooling zone are not partitioned so that all zones are maintained in the same atmosphere, thus making the reaction at the surface of the steel sheet at the time of annealing more uniform and improve the plating appearance. The inventors have discovered that by including in the atmosphere of the reducing zone a suitable amount of CO₂ in addition to H₂ with a balance of N₂, H₂O, O₂, CO, and properly selecting the partial pressures, it is possible to cause internal oxidation of SiO₂ without generating iron oxides.

According to the specification, in conventional processes for plating a high strength steel sheet containing elements such as Si and P, use of an oxidizing zone to make iron oxide film in a suitable thickness is necessary (the specification at p. 1, l. 35 to p. 2, l. 16). The cited

reference JP '412 discloses such a conventional process which uses a furnace wherein iron is oxidized in an oxidation zone, and thereafter, the generated iron oxide is reduced in a reducing zone. JP '412 teaches generating Fe oxide of several thousands Å to suppress the formation of Si oxides on the surface (*see* JP '412, paragraphs [0021]). The steel is then reduced in a reducing zone having an atmosphere with N₂ gas containing 1-70% of H₂ to reduce Fe oxide and cause internal oxidation of SiO₂ (*see* JP '412, paragraph [0023]). Therefore, JP '412 teaches a conventional production process that is a different production process of the present invention.

US '905 teaches a process for continuously annealing a cold-rolled low carbon steel strip in a direct fire furnace. US '905 is not concerned with galvanizing a high strength steel sheet containing elements such as Si and P using an all radiant tube type annealing furnace, nor the problem of formation of Si oxides on the surfaces of such steel sheet. In the process of US '905, the steel strip is rapidly heated in an oxidizing atmosphere with gaseous combustion prepared at a combustion air ratio of 0.8 or more but less than 1.0 in a direct fired furnace so as to control the thickness of a layer of oxides on the surface of the steel strip to not exceeding 1000 Å (*see* US '905, the abstract, col. 3, ll. 39-49, and col. 8, ll. 51-57). US '905 discloses that the steel strip is then reduced in a reducing zone containing 4% or more of hydrogen gas with the balance consisting of nitrogen gas (*see* US '905 at col. 9, ll. 58-62; col. 12, ll. 41-47). Therefore, US '905 also teaches a process that includes a step of oxidizing and a step of reducing in a reducing zone having an atmosphere of N₂ and H₂, which is different from the present invention which uses an all radiant tube furnace without an oxidization zone.

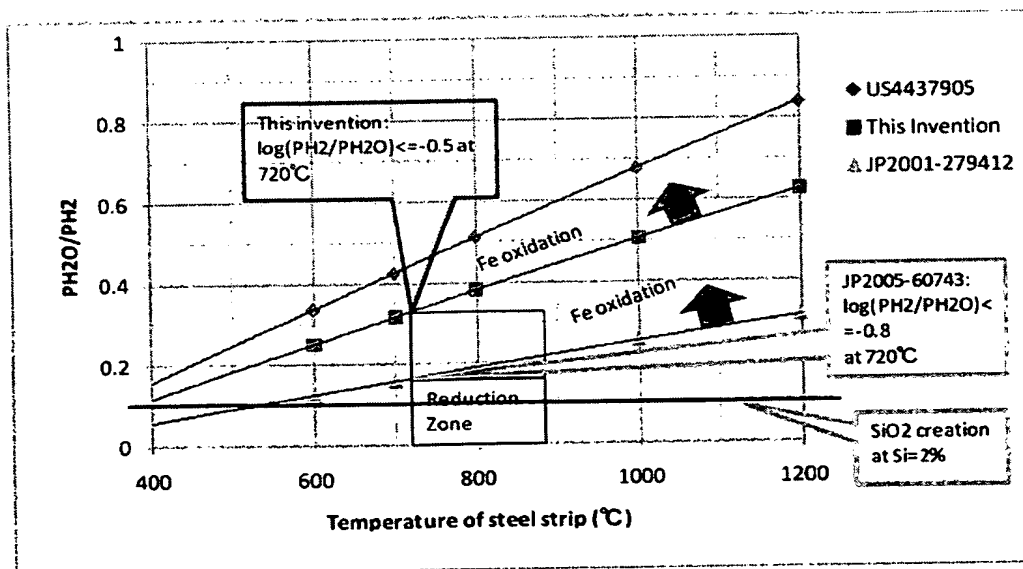
In the process of the present application, the conditions are provided to cause internal oxidation of SiO₂ without generating iron oxides to reduce SiO₂ formation on the surface of a steel sheet, e.g., by controlling $\log(\text{PCO}_2/\text{PH}_2)$ to ≤ -0.5 , $\log(\text{PH}_2\text{O}/\text{PH}_2)$ to ≤ -0.5 , and $\log(\text{P}_T/\text{PH}_2)$ to $-3 \leq \log(\text{P}_T/\text{PH}_2) \leq -0.5$ when using the all radiant tube type annealing furnace, and also making the atmosphere of a reducing zone to include a balance of N₂, H₂O, O₂, CO₂, CO, and unavoidable impurities.

In particular, the presence of CO₂ and CO makes it possible to eliminate the formation of iron oxide at $\log(\text{PH}_2\text{O}/\text{PH}_2)$ to ≤ -0.5 . Applicants have discovered that the formation of iron oxide can be prevented by expanding the range of $\log(\text{PH}_2\text{O}/\text{PH}_2)$ to ≤ -0.8 in JP '412 to the claimed range of $\log(\text{PH}_2\text{O}/\text{PH}_2)$ to ≤ -0.5 by adding CO₂ and CO. In the process of JP '412, on the other hand, the reducing zone contains N₂ gas with H₂ gas in the range of 1 to 70% (*see* JP '412, paragraph [0022]).

Figure A below shows the relationship between the ratio of water partial pressure and hydrogen partial pressure $\text{PH}_2\text{O}/\text{PH}_2$ and the temperature of the steel strip ($^{\circ}\text{C}$) in connection with the present invention, cited references JP '412 and US '905. As seen from Figure A, the region of iron oxide formation may overlap the region of SiO_2 formation at low temperature. However, Applicants have found that when using the all radiant furnace, the $\text{PH}_2\text{O}/\text{PH}_2$ ratio can be maintained constant through out without forming iron oxide at low temperature range, and without forming SiO_2 . Applicants have also found that when $\log(\text{PT}/\text{PH}_2)$ is controlled to at least -3, the formation of SiO_2 can be prevented, which causes the region for iron oxide formation not to overlap with the region for SiO_2 formation at low temperature.

In contrast, JP '412 does not teach or suggest adding CO_2 to the reduction atmosphere and to control the conditions such as $\text{PH}_2\text{O}/\text{PH}_2$ to promote internal oxidation of SiO_2 . The reducing zone of JP '412 contains N_2 gas with H_2 in the range of 1-70 mass% (see paragraph [0021] of JP '412). In addition, JP '412 only teaches controlling $\text{PH}_2\text{O}/\text{PH}_2$ in its reducing zone. The $\text{PH}_2\text{O}/\text{PH}_2$ ratio line for the formation of SiO_2 would intersect the $(\text{PH}_2\text{O}/\text{PH}_2)$ ratio line for the iron oxide formation in JP '412 at approximately 500°C . Thus, if an all radiant furnace is used as the reducing zone in JP '412, iron oxide would be created in the stage prior to the reducing zone (soaking zone), and the amount (or thickness) of this iron oxide film can increase or decrease as the moving rate of the steel sheet changes, i.e., it would be difficult to control the amount of iron oxide generated. Therefore, in view of the above, the process of JP '412 cannot be used in an all radiant furnace.

Figure A



With respect to the Examiner's contention that US '905 supplies the teaching of including O₂, CO₂ and CO in the atmosphere of the reducing zone, US '905, however, does not teach adding O₂, CO₂, and CO to the reducing atmosphere. US '905 teaches including CO₂ in the oxidizing zone, and only N₂ and H₂ is added to the reducing zone. For example, US '905 discloses that its reducing atmosphere contains 4% or more of hydrogen gas with the balance consisting of nitrogen gas (*see* US '905 at col. 9, ll. 58-62; col. 12, ll. 41-47). Therefore, the addition of O₂, CO₂ or CO to the reducing atmosphere is not taught by US '905.


Therefore, neither JP '412 nor US '905 is concerned with the problem solved by the present invention, i.e., hot-dip galvanizing a high strength steel sheet containing elements such as Si and P using an all radiant tube type annealing furnace without an oxidizing zone. Neither JP '412 nor US '905 teaches or suggests the solution of the problem, i.e., using an atmosphere having CO₂ and suitably controlling the partial pressures to cause internal oxidation of SiO₂ without a step of generating iron oxides. Both JP '412 and US '905 teach processes utilizing an oxidizing zone to first generate a layer of iron oxides on the steel sheet surface, and a reducing zone containing N₂ and H₂ to reduce iron oxides and generating internal Si oxides. One skilled in the art would not have arrived at the process of the present invention based on the teachings of JP '412 and US '905. Therefore, JP '412, in view of US '905 cannot render the presently claimed invention obvious. Accordingly, the rejection of claims 1-3 under 35 U.S.C. §103(a) as obvious over JP '412 in view of US '905 cannot stand and should be withdrawn.

In view of the foregoing amendments and remarks, Applicants respectfully submit that the present application is in condition for allowance. Early and favorable action by the Examiner is earnestly solicited. If the Examiner believes that issues may be resolved by a telephone interview, the Examiner is invited to telephone the undersigned at the number below.

Respectfully Submitted,

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